

What is claimed is:

1. A method for comparing first and second laser pulses output from first and second short-pulse laser sources, respectively, comprising the steps of:

(a) detecting a temporal difference between the first and second laser pulses;

(b) generating a control signal based on said temporal difference detected in step (a); and

(c) continually adjusting the output of said second laser source based on said control signal to thereby control said temporal difference between the first and second laser pulses.

2. A method for rapidly scanning a first pulse output from a first short-pulse laser and a second pulse output from a second short-pulse laser, comprising the steps of:

detecting a difference between the first and second pulses;

generating a time delay control signal based on said difference detected in said detecting step;

altering a time delay of the second pulse by changing the frequency of pulses output from the second short-pulse laser based on said time delay control signal, thereby stabilizing the second pulse with respect to the first pulse; and

scanning the first pulse and the second pulse altered in said altering step, by changing the time delay of one of the first and second pulses in a predetermined manner.

3. The method for scanning as claimed in claim 2, wherein in said step of altering a time delay by changing the frequency of pulses output from the second short-pulse laser is performed by changing the length of a laser cavity of

the second short-pulse laser, and in said scanning step the time delay of one of the first and second pulses is changed by changing the length of the laser cavity of one of the first and second short-pulse lasers, respectively.

4. The method for scanning as claimed in claim 3, wherein the length of a laser cavity of said one of the first and second short-pulse lasers is changed in said scanning step in said predetermined manner by applying one of a square wave, a rectangular wave and a sinusoidal wave to a piezoelectric unit disposed within the laser cavity of said one of the first and second short-pulse lasers.

5. A fast scanning laser apparatus, comprising:
a signal generator which outputs a dithering signal; and
first and second short-pulse lasers each having a laser cavity, wherein at least one of said first and second lasers has a length changing unit disposed within its laser cavity, said length changing unit changing the length of said laser cavity based on said dithering signal.

6. The fast scanning apparatus as claimed in claim 5, further comprising:

a stabilizer which generates a control signal based on timing differences between a first pulse output from said first laser and a second pulse output from said second laser, and which outputs said control signal to said length changing unit which thereby changes the length of said laser cavity based on said control signal and said dithering signal.

7. The fast scanning apparatus as claimed in claim 6, wherein said stabilizer comprises:

a phase lock loop circuit for detecting and controlling a phase difference between a first pulse output from said first short-pulse laser and a second pulse output from said second short-pulse laser;

means for generating the control signal based on the phase difference detected by said phase lock loop circuit, and adjusting and outputting said control signal.

8. The fast scanning apparatus as claimed in claim 5, wherein said length changing unit comprises a mirror mounted on a piezoelectric device.

9. A short-pulse laser apparatus, comprising:

laser generating means for outputting a laser beam comprised of one or more ultrashort pulses;

a moving device cooperating with said laser generating means to cause an effective length of said laser generating means to be changed thereby changing the repetition rate of said laser beam.

10. The short-pulse laser apparatus claimed in claim 9, wherein said laser generating means has an end and said moving device is disposed at said end of said laser generating means;

11. The short-pulse laser apparatus claimed in claim 10, wherein a mirror is mounted on said moving device, and said moving device causes said mirror to move which causes an effective length of said laser generating means to be changed thereby changing the repetition rate of said laser beam.

12. The short-pulse laser apparatus as claimed in claim 11, wherein said moving device is a piezoelectric element.

13. The short-pulse laser apparatus claimed in claim 9, wherein said moving device is a drum having an changeable diameter, and said laser generating means is a fiber wrapped on said moving device, wherein when said diameter of said moving device changes an effective length of said laser generating means changes thereby changing the repetition rate of said laser beam.

14. The short-pulse laser apparatus as claimed in claim 13, wherein another laser generating means is wrapped on the same drum as said laser generating means.

15. The short-pulse laser apparatus as claimed in claim 14, wherein said moving device is a piezoelectric drum.

16. An apparatus for measuring a distance, comprising:

a first short-pulse laser, comprising:

laser generating means for outputting a laser beam comprised of a first ultrashort pulse; and

a moving device cooperating with said laser generating means to cause an effective length of said laser generating means to be changed thereby changing the repetition rate of said laser beam;

a second short-pulse laser outputting a second ultrashort pulse;

an optical element for producing a sequence of pulses from said second pulse;

a timing unit for correlating said first pulse with said sequence of pulses produced by said optical element and outputting a calibration signal indicating a calibration of said second pulse with respect to said sequence of pulses;

an optical output device for outputting said first pulse to an object under test, and receiving a reflected pulse corresponding to a reflection of said first pulse by said object;

a correlator for correlating said reflected pulse with said second pulse and outputting a correlated signal; and

a data acquisition unit for comparing said correlated signal with said calibration signal.

17. The apparatus for measuring a distance as claimed in claim 16, wherein the apparatus is employed in a metrology system, said object under test is a surface, and said optical output device is a lens for focussing said first pulse onto said surface.

18. The apparatus for measuring a distance as claimed in claim 16, wherein the apparatus is an optical time domain reflectometer, wherein said object under test is an optical fiber and said reflections are reflections of said first pulse from optical discontinuities within said optical fiber.

19. An apparatus for measuring a distance, comprising:

a first short-pulse laser, comprising:

laser generating means for outputting a laser beam comprised of a first ultrashort pulse; and

5 a moving device cooperating with said laser generating means to cause an effective length of said laser generating means to be changed thereby changing the repetition rate of said laser beam;

a second short-pulse laser outputting a second ultrashort pulse;

an optical element for producing a sequence of pulses from said first pulse;

an optical output device for outputting said first pulse to an object under test, and receiving a reflected pulse corresponding to a reflection of said first pulse by said object; and

a correlator for correlating said reflected pulse with said second pulse and with said sequence of pulses produced by said optical element, said correlator outputting a signal corresponding to the correlation of said second pulse with said reflected pulse which is superimposed on said sequence of pulses.

20. An electro-optic sampling oscilloscope, comprising:

a first short-pulse laser, comprising:

laser generating means for outputting a laser beam comprised of a first ultrashort pulse; and

5 a moving device cooperating with said laser generating means to cause an effective length of said laser generating means to be changed thereby changing the repetition rate of said laser beam;

a second short-pulse laser outputting a second ultrashort pulse;

10 an optical element for producing a sequence of pulses from said second pulse;

a timing unit for correlating said first pulse with said sequence of pulses produced by said optical element and outputting a calibration signal indicating a calibration of said second pulse with respect to said sequence of pulses;

5 a optical output device for outputting said first pulse to a device under test, thereby enabling a signal on said object under test;

a probe for outputting said second pulse to a point to be measured on said device under test, and receiving a returned signal, wherein said returned signal is altered by an interaction between said enabled signal on said device under test and said second pulse output by said probe;

a data acquisition unit for comparing said correlated signal with said returned signal, thereby providing a high precision time base.

21. A method for controlling the stability of a short-pulse laser, comprising the step of:

isolating said short-pulse laser from an external environment, wherein the short-pulse laser is a fiber laser, by wrapping said fiber laser on a fiber spool.

22. The method for controlling the stability of a short-pulse laser claimed in claim 21, wherein said fiber spool is acoustically damped.

23. The method for controlling the stability of a short-pulse laser claimed in claim 21, wherein the thermal expansion of said fiber spool is matched to that of said optical fiber.

24. The method as claimed in claim 21, wherein said short-pulse laser is a first short-pulse laser and the stability of a second short-pulse laser is controlled along with that of the first short-pulse laser and where the first and second short-pulse lasers are fiber lasers, the method comprising the steps of:

5 constructing the first and second short-pulse lasers from identical components in an identical fashion; and

pumping the first and second short-pulse lasers with a shared laser;

wrapping the first and second short-pulse lasers on a shared fiber spool;
and
placing the first and second short-pulse lasers in a single enclosure.

25. A method for controlling the stability of a short-pulse laser, comprising the step of:

operating the short-pulse laser near a zero-dispersion wavelength thereby minimizing quantum-limited timing jitter.

26. A method for controlling the stability of a short-pulse laser, comprising the step of:

placing the short-pulse laser in an enclosure that is at least one of acoustically damped and temperature controlled.

27. An apparatus for generating a calibrated time scale, comprising;
a laser which outputs ultrashort pulses;

an optical element which produces a sequence of pulses spaced apart by a known time when each said pulse output from said laser is incident upon said optical element.

28. The apparatus for generating a calibrated time scale claimed in claim 27, wherein said optical element is selected from the group of elements consisting of:

an optical etalon formed in an optical fiber cavity with end reflectors comprised of one of dielectric mirrors and photo-refractive fiber gratings;

an optical resonant reflector;

an optical fiber with misaligned splices to produce reflections;

an optical fiber with a plurality of photorefractively grown fiber gratings having a predetermined reflectivity and spacing;

an optical fiber with micro-bends placed to produce reflections at desired time intervals;

5 a semiconductor laser diode biased near a threshold to produce repetitive pulses, thereby preventing or retarding the decay of an optical pulse train;

a linear Fabry-Perot cavity containing optical fiber gain medium pumped near a threshold to produce repetitive pulses, thereby preventing or retarding the decay of an optical pulse train;

10 a passive optical fiber loop for storage of one or more pulses, said fiber loop being injected and dumped by an optical switching element;

an amplifying optical fiber loop for storage of one or more pulses, said fiber loop being injected and dumped by an optical switching element; and

15 a multimode optical fiber where modal dispersion creates different arrival times for pulses traveling in different transverse modes.

29. The apparatus for generating a calibrated time scale as claimed in claim 27, wherein said optical element is a pulse train generator comprising:

a first optical fiber having a plurality of photorefractively-grown chirped fiber gratings chirped in a first direction;

5 a second optical fiber having a plurality of photorefractively-grown chirped fiber gratings, substantially the same as in the first optical fiber, chirped in a second direction which is opposite to said first direction; and

means for directing said pulse output from said laser to one of said first and second optical fibers and receiving a first reflected plurality of pulses therefrom, and directing said first reflected plurality of pulses to the other of said first and second optical fibers and receiving a second reflected plurality of pulses

therefrom, and outputting said ~~second~~ reflected plurality of pulses as the calibrated time scale.

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